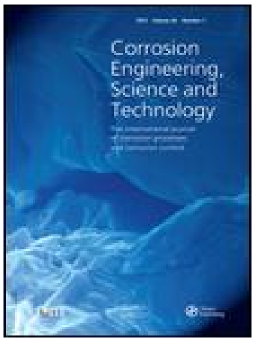

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Covid-19: effect of disinfection on corrosion of surfaces

L. Bonin [a], V. Vitry [b], M.-G. Olivier [c] and L. Bertolucci-Coelho [c]

[a]Center for Microbial Ecology and Technology (CMET), Campus Coupure – Ghent University, Ghent, Belgium; [b]Metallurgy Lab, University of Mons, Mons, Belgium; [c]Materials Science Department, Faculty of Engineering, University of Mons, Mons, Belgium

ABSTRACT

In suspected cases of COVID-19 infection, the World Health Organization has recommended the thorough cleaning of surfaces and the application of commonly used hospital-level disinfectants are effective procedures. The new virus situation has changed the sanitary habits of industries and this will potentially have anadverse effect on surfaces highly exposed to disinfectants that are often chlorinated. Therefore, the corrosion community should be concerned if the sudden increased use of disinfectants on certain surfaces would alter their corrosion rate/mechanism in the short-medium term. This technical note also provides recommendations for forfuture studies to face these urgent surface challenges.

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Introduction

COVID-19 is a new respiratory virus which spreads primarily through contact with an infected person. Although there is good evidence the novel coronavirus is one of the easiest types of virus to kill, scientists are still determining its exact nature and the role of surfaces in spreading the contaminant. Regarding coronavirus survival time on surfaces, a review byG. Kampf et al. [1] indicated significantvariabilityranging from two hours to nine days and dependingupon factors such as type of surface (e.g. copper, stainless steel, ceramic), temperature, relative humidity and specific strain of the virus. The same review pointed out that effective inactivation could be achieved by usingcommon disinfectants such as sodium hypochlorite (bleach). Similarly, A. Chin et al. [2] provided the coronavirus' lifespan on a range of household surfaces, including refrigerators, pots and pans, sinks, water bottles (stainless steel: 2–3 days); pennies, teakettles, cookware (copper: 4 h); soda cans, tinfoil, water bottles (Al: 2–8 h); dishes, pottery, mugs (ceramics: 5 days). An important question remaining to be addressed is what would be the case for metallic objects presenting a corroded (oxidised) surface instead of a pristine one.

In suspected cases of novel coronavirus (nCoV) infection, the World Health Organization (WHO) recently recommended the appropriate and consistent use of environmental cleaning and disinfection procedures, asserting that the thorough cleaning of environmental surfaces and the application of commonly used hospital-level disinfectantsare sufficient and effective procedures. Hence, the spread of the COVID-19 disease has spurred a surge in sales of cleaning and disinfection products. The corrosion community should be concerned if the sudden increased use of disinfectants on certain surfaces would alter their corrosion rate/mechanism in the short-medium term.

One out of five disinfectantslisted by the U.S. Environmental Protection Agency as effective against the virus [3] comprises chlorinated compounds, the majority of them being sodium hypochlorite-based. While this at least implies that four out of five disinfectants pose little or no risk to metals, only a limited amount ofstudyhas beendevoted to the corrosion of materials exposed to disinfectant agents. However, the COVID situation has changed the sanitary habits/protocol of industries andthis will potentially have a negative effect on surfaces highly exposed to hypochlorites, from the corrosion point of view.

The role of sodium hypochlorite in accelerating corrosion

Hypochlorites(ClO^-) are alkaline oxidising agents and are corrosive. In addition, commercial hypochlorite products always contain significant amounts of sodium chloride, another corrosive species. Yet, B. Gaur [4] noted that hypochlorite solutions are employed by various industries, under appropriate recommendations, for bleaching and sanitising. Here, the end-use concentration depends on the Standard Operating Procedure for each facility. Bleach solutions must remain wet on the surface for an adequate amount of time to be effective as disinfectants. This is often referred to as Contact Time or Dwell Time and can vary depending on the dilution and the target microorganism. For example, a 10 minute contact time with a higher-strength solution containing at least 5000 ppm is recommended by the Center for Disease Control (CDC) to kill Clostridium difficile. After sufficient contact time, the surface should be rinsed with clean water to remove bleach residue [5].

Experiments conducted by B. Gauron mild steel exposed to hypochlorite solutions have indicated a corrosion rate increase proportional to thefree available chlorine concentration. Similarly, a study of Oliet et al. [6] has demonstrated the corrosive effect of hypochlorite on carbon steel endodontic instruments. Hypochlorite is also aggressive towards the most-used grades of stainless steel, 304 and 316, constituting a hazard for pittingcorrosion. In the presence of aggressive anions, such as Cl^- and ClO^-, the passive film undergoes local damage, which initiates the process of pitting. As reported by Pierozynski and Kowalski [7], the in-situ

CONTACT L. Bertolucci-Coelho leonardo.bertoluccicoelho@umons.ac.be Materials Science Department, Faculty of Engineering, University of Mons, 20 Place du Parc, 7000 Mons, Belgium

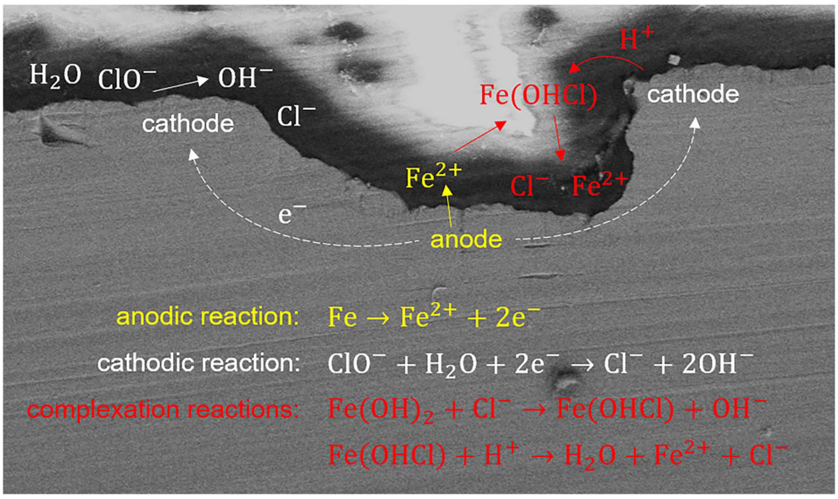

Figure 1. Scheme of pitting corrosion of stainless steel induced by hypochlorite.

produced Cl^- ion creates ideal conditions for the initiation of pitting. Martins et al. [8] attribute the action of hypochlorite on stainless steel to the cathodic reaction presented in Equation (1), which is an alternative to oxygen reduction:

$$ClO^- + H_2O + 2e^- \rightarrow Cl^- + 2OH^-. \quad (1)$$

The ongoing adsorption of Cl^- on the steel surface promotes the formation of intermediate complexes, leading to the dissolution of the passive film (nucleation for pitting corrosion), as schematically presented in Figure 1.

In addition, corrosion tests performed on copper [9] have highlighted the increase of corrosion rate and Cu release with increased chlorine concentration. As summarised by Atlas on the corrosion of Cu by chlorinated drinking waters [10], the metal is prevented from corrosion only if chlorine concentration is maintained below ~2 mg/L.

Commercially concentrated hypochlorite is around 15wt-%, while household bleach solutions are around 5.25%, hypochlorite. For the disinfection of surfaces from COVID-19, the WHOhas recommended the use of sodium hypochlorite at 0.5% (equivalent 5000 ppm) [11]. For the sake of avoiding surface damage, Health Institutes have explicitly recommended rinse-off in the case of concentrations eventually exceeding 0.5% [12]. However, according to the Guide to Hygiene and Sanitation in Aviation, the disinfectant residual for chlorine should typically be no more than 5 ppm [13]. Moreover, concerning 316 stainless steel, previous studies have indicated that an appropriate threshold value for the residual chlorine concentration would be about 25 mg/L [14]. Therefore, there are risks of corrosion because the rinse-off procedure is only recommended for cases with the highest disinfectant concentration (5000 ppm). Furthermore, the current rinse-off protocol lacks in precise recommendations: 'To effectively kill the virus, make sure the surface stays wet with the disinfectant for at least 10 min before wiping with a clean towel. Rinse with water and allow surface to air dry' [15]. So, how can the concentration be decreased in the absence of clear rinse-off recommendations? Can the current rinse-off procedures be trusted to be put into action? As the rinse-off procedure is not well-defined, there is the risk of attaining residual concentrations higher than those typically recommended. This information should urgently be disseminated to make sutre people do not overuse hypochlorite-based treatments on metal surfaces

Susceptibility of aeroplanes to the risk of corrosion from sanitary products

Although many aeroplanes have been mothblalled, airplanes that are still in useface strong sanitation protocols. Although the residual disinfectant chlorine should not generally exceed 5 mg/L in the aircraft [13], the present sanitary crisis calls foreffective chlorine concentrations of 25-500 mg/L for 10 mins of reaction time or around 1000 mg/L for 30 min of reaction time [16]. These datademonstrate the current challengesin keeping disinfected surfaces withinsafe limits of chlorine concentration such that structurally damaging effects upon the aircraft are avoided [17].

Aluminium, a main constituent material of airplanes, withstands cleaning solutions when the contact is short, intermittent, and followed by rinsing with water. For prolonged contact, however, the addition of a corrosion inhibitor such as 2% sodium silicate is recommended [18]. If the good practice recommendations are not respected, Al is certainly prone to corrosion in the presence of hypochlorite. Indeed, as commercial hypochlorite solutions typically have a pH of 11–12, the general corrosion attack of Al is expected, resulting in a thickness decrease of 0.5 mm per year for 1100 and 5754 Al alloys. Furthermore, Cu-containing alloys of the 2000 series (extensively used in aeronautics) are even more corrosion-sensitive to hypochlorite, presenting a corrosion rate about 30 times higher than that of AA1100.

Conclusions and recommendations

Future studies could focus on surface modification technologies that decrease virus lifetime while not being detrimental tothe primary properties of the material. For instance, would there be a difference in terms of virus residence times depending on the metal surface state (roughness, presence of passive layer, rust)?

One necessary research topic would be the influence of different concentrations/contact times of chlorinated disinfectants on a variety of metal surfaces, such as 304 and 316 stainless steels and other relevant materials for medical environments. Investigations on the corrosion mechanism would allow a suitable selection of corrosion inhibitors that do not decrease the effectiveness of the sanitation process. These inhibitors could be applied to protective coatings and/or directly incorporated in the rinsing solutions.

Although this note mainly focuses on chlorine-related issues, alternative surface disinfection methods even less studied by corrosionists (UV treatments, peroxideor cationic alkyl ammonium saltssanitation, etc.) would most likely have secondary detrimental effects. Appropriate monitoring of surface degradation in these highly oxidising media would require updating maintenance protocols as well.

Novel sensor technologies and long-term prediction tools will be important allies for tackling all these problems. Appropriate corrosion control could be achieved if strategic research topics are considered and planned in advance. Finally, multidisciplinary research approaches should be considered to face these urgent surface challenges.

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ORCID

L. Bonin http://orcid.org/0000-0001-7123-0012
V. Vitry http://orcid.org/0000-0002-9155-7271
M.-G. Olivier http://orcid.org/0000-0001-7771-7454
L. Bertolucci-Coelho http://orcid.org/0000-0002-7106-7603

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